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(54) Power amplifying arrangement

(57) A power amplifying arrangement which amplifies pulse envelope signals in a manner which avoids the generation of transient sidebands and interference on adjacent channels.

The arrangement comprises means (44,46,48,54) for generating a reference waveform corresponding to a predetermined desired shape, for example raised cosine, of the output power from a power amplifier (34). A power sensor (36) is provided for sensing the output of the power amplifier (34) and for producing a voltage which follows the envelope of the RF signal. This voltage is compared with the reference waveform in a comparator (58). The differences between the signals at the inputs (56,60) to the comparator (58) are used to control the output power of the amplifier (34).

Applications for such a power amplifying arrangement are in TDMA digital signalling systems such as cellular telephone systems in which not only is it desired to minimise the generation of unwanted transient sidebands and interference on adjacent channels but also the output power can be set to one of a number of predetermined output levels.

Fig.4.

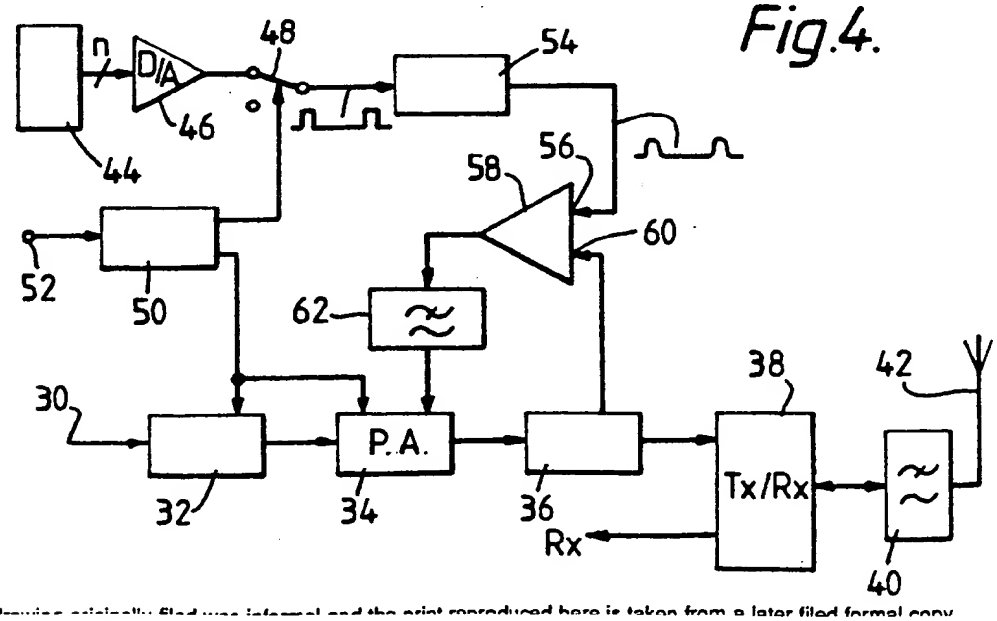

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Fig.1.

Fig.2.

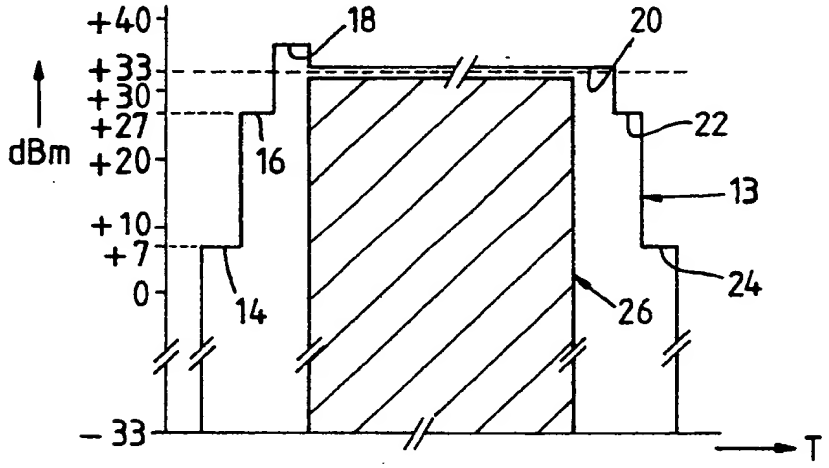


Fig.3.

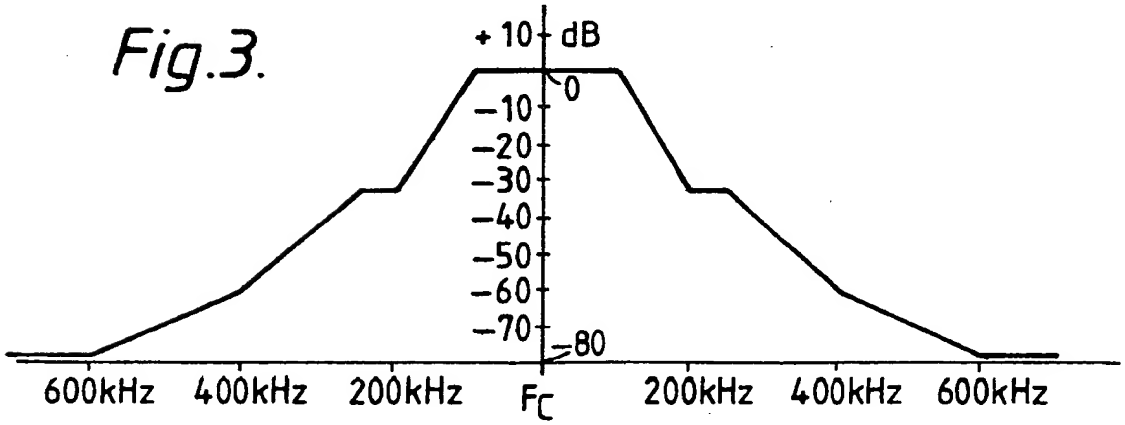


Fig.4.

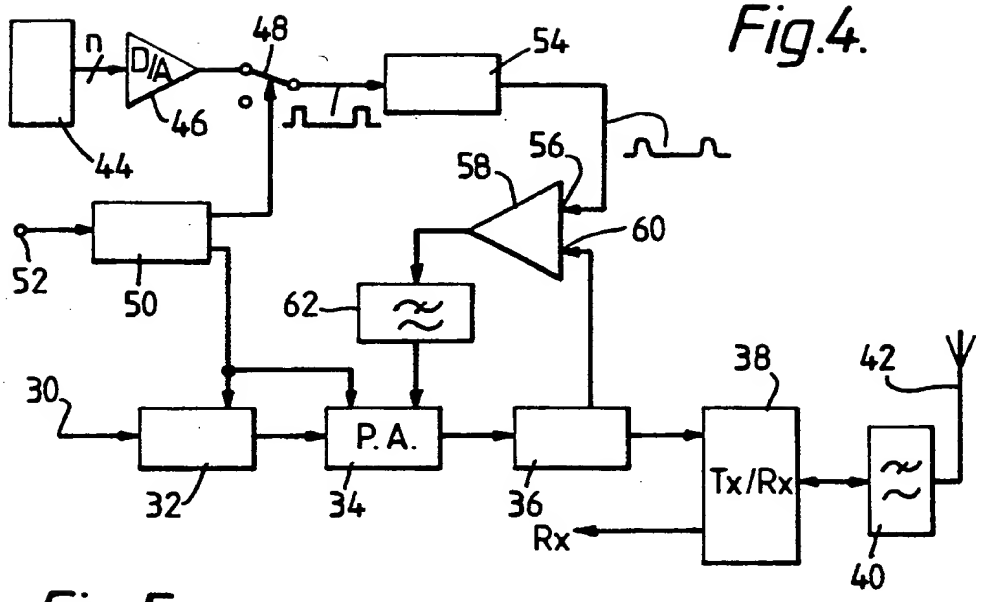


Fig.5.

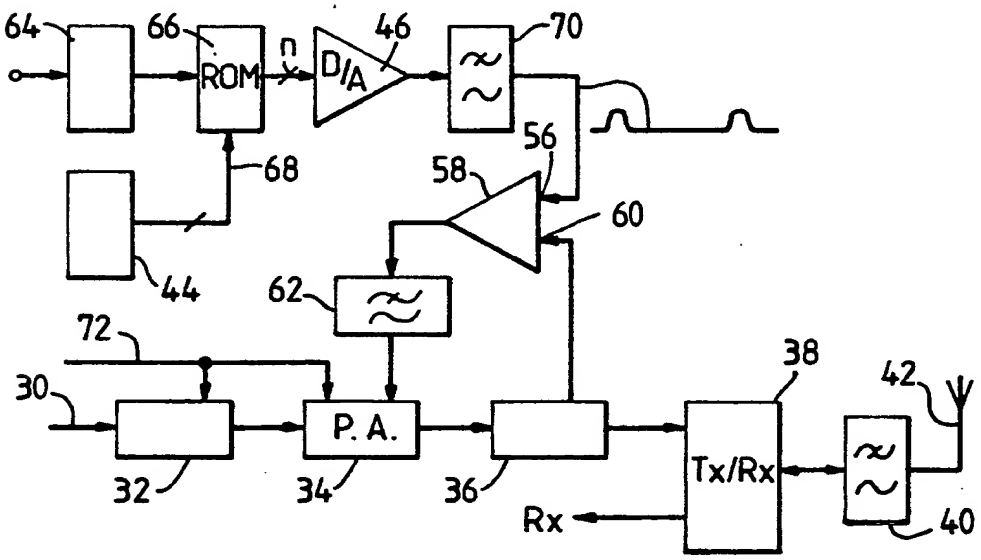
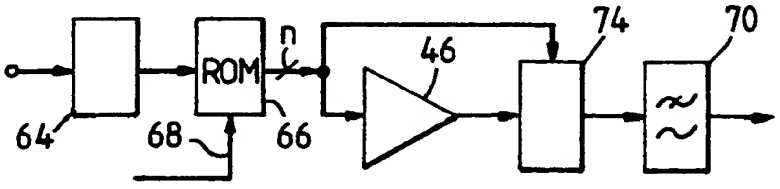


Fig.6.



DESCRIPTION

POWER AMPLIFYING ARRANGEMENT

The present invention relates to a power amplifying arrangement suitable for sending pulses of power containing digital data.

A problem when transmitting pulses of r.f. energy is that if the rising and trailing edges are very sharp then they will give rise to sharp switching transients which cause what is termed "splatter" on adjacent channels, by splatter is meant the generation of transient sidebands and interference on adjacent channels. A known technique for avoiding splatter is to shape the leading and trailing edges of the pulses by for example ramping and/or rounding of the edges. A known shaping characteristic is called raised cosine shaping. In practical applications such as digital cellular telephone systems operating in TDMA the output signal power produced either by a base station or by a mobile is related to the range to be covered, that is communication between two nearby pieces of equipment is carried-out at a lower power than two pieces of equipment which are relatively distant with respect to each other. Accordingly the waveform shaping applied should be suitable for varying output powers. At the same time the signal as transmitted must conform to a defined frequency spectrum specification which cannot be achieved by hard switching.

An object of the present invention is to produce an amplified pulse of R.F. power containing digital data, which pulse can have a selected one of a predetermined number of power levels and have a modulation mask conforming to a desired frequency spectrum specification.

According the the present invention there is provided a power amplifying arrangement comprising a power amplifier stage having an input for a signal to be amplified, an output for a signal amplified by the power amplifier and a control input for setting the instantaneous output power of the amplifier, a power sensor coupled to the output of the amplifier, the power sensor

having a first output for the amplified signal and second output for providing a signal representative of the instantaneous value of the amplified signal, a comparator having first and second inputs and an output, the first input being coupled to the second output of the power sensor, the second input being coupled to means for providing a reference waveform of the output signal, the output being coupled to the control input of the amplifier.

The power amplifying arrangement is able to produce pulses of r.f. energy comprising modulated digital data having the desired output power and the desired frequency spectrum specification by providing a servo loop in which the amplified output signal is sensed and the sensed voltage is applied to a first input of a comparator in which it is compared to a locally generated reference waveform applied to the second input of the comparator. By using this servo loop technique the power amplifier need not have a critical specification and hence is easier and cheaper to implement.

In one embodiment of the present invention the means for providing a reference waveform comprises a device for producing digital data representative of a desired reference level, a digital-to-analogue converter for producing a voltage in response to the digital data, means for producing a pulse waveform from the voltage and a shaping filter for shaping the pulses of voltage to a predetermined shape.

In a second embodiment of the present invention the means for providing a reference waveform comprises a ROM for storing digitally patterns of different waveform shapes, the ROM having a first input for a power level signal, a second input for clock signals and an output, a digital-to-analogue converter coupled to the output of the ROM and a clock signal removing filter coupled in the analogue signal path from the digital to analogue converter.

In a third embodiment of the present invention an attenuator is connected to the signal output from the digital-to-analogue converter, the attenuator being switchable to provide a desired

output range. The attenuator may comprise a tapped resistive ladder adapted to provide a non-linear set of full scale outputs.

The power amplifying arrangement may further comprise means for enabling the power amplifier stage so that it is activated whenever there is a pulse of power to be amplified. The provision of such enabling means prevents r.f. leaking through to the antenna in an interpulse period.

The power amplifier arrangement may further comprise switching means having an input for a signal to be amplified and an output coupled to the input of the power amplifying stage, the switching means being actuated by the means for enabling the power amplifier stage. The provision of the switching means further prevents r.f. leaking through to the amplifier input during an interpulse period.

The present invention will now be described, by way of example, with reference to the accompanying drawings, wherein:

Figure 1 illustrates a typical pulse waveform,

Figure 2 illustrates an example of a time mask of the envelope of the RF waveform at the output of the power amplifier arrangement,

Figure 3 is a graph illustrating an example of a frequency spectrum specification, the ordinate represents relative power in dB and the abscissa the frequency relative to the centre frequency F_C,

Figure 4 is a block schematic diagram illustrating a first embodiment of the present invention,

Figure 5 is a block schematic diagram illustrating a second embodiment of the present invention, and

Figure 6 is a block schematic diagram of a pseudo-linear digital to analogue converter.

In the drawings the same reference numerals have been used to indicate corresponding features in the respective embodiments.

For ease of description the present invention will be described in respect of a power amplifying arrangement for use in the GSM (Group Special Mobile) digital cellular telephone

system. However the arrangement may be used in other applications requiring the transmission of pulses of r.f. digitised signals. The GSM system is a TDMA one having a signalling format includes a framed structure comprising eight slots each having a duration of approximately 570μS. Transmissions are made in the first slot and reception is in one of the remaining seven slots. An 8:1 time compression is used which results in a peak to average transmit power level of 8:1. A feature of the GSM specification is that the power amplifying arrangement must be capable of adaptive power control in that the transmitted power is adjusted in steps to suit the required transmission range. The size of the steps are 2dB and there are 16 steps ranging from a maximum peak power of 43dBm to a minimum peak power of 13dBm. Another factor which has to be taken into account, particularly because the GSM system is a TDMA one, is the frequency spectrum specification which is achieved by shaping of the leading and trailing edges 10, 12 (Figure 1) to reduce the risk of generating sidebands and interference on adjacent channels. The shaping of these edges may vary from one power step to the next but it is particularly important to apply shaping to the higher powered signals. A typical shaping profile is known as raised cosine.

Figure 2 illustrates an example of a time mask of the envelope of the RF waveform at the output of the power amplifier arrangement. The abscissa represents time, T, and the ordinate represents the power level of the power amplifier in dBm. Figure 2 illustrates the outer and inner limits 13 and 26, respectively, of the envelope of the output of the power amplifier. By defining the outer and inner limits then the envelope of the RF waveform has to lie somewhere between them. In this example the desired output power is +33dBm. The actual shape chosen has to be a compromise between the time and frequency spectrum specifications. The frequency spectrum specification is shown in Figure 3.

The inner limit 26 has a duration of the order of 542.8μS

which corresponds to 147 bit periods of the GSM signal. This limit 26 corresponds to hard switching which is undesirable because of the generation of transient sidebands and interference on adjacent channels making it impossible for the frequency spectrum specification to be achieved.

The outer limit 13 has stepped leading and trailing edges. The stepped leading edge comprises steps 14 and 18 of 10μS duration and the intermediate step 16 of 8μS duration. The stepped trailing edge is formed by a portion 20 of the upper power limit which extends 10μS beyond the termination of the inner limit 26, a step 22 of 8μS and a step 24 of 10μS. This outer limit 13 is acceptable in the time domain but unacceptable in the frequency domain.

The first embodiment of the invention shown in Figure 4 comprises an input 30 for a low powered (1mW) GMSK modulated RF signal. The signal is applied to a power amplifying (PA) stage 34 by way of a PIN switch 32. An output of the PA stage 34 is connected to a power sensing stage 36 which has an output connected to a transmit/receive switch 38. An output from the switch 38 is connected to an antenna 42 by way of a low pass filter 40.

The power amplified signal from the P.A. stage 34 comprises shaped pulses of r.f. power having a predetermined level which may be changed as required. In order to fulfil both requirements in a practical way, a microcontroller 44 is provided which in response to external information regarding range sends an n-bit parallel signal indicating the required power output to a digital to analogue converter 46 which provides as an output a d.c. related to the required power. The d.c. signal is applied to a switch 48 which is controlled by a switch sequencer 50. The switch sequencer 50, in response to an external control signal on terminal 52, applies a 12.5% duty cycle on the switch 48. The output from the switch 48 comprises substantially rectangular pulses. The leading and trailing edges of these pulses are shaped in a pulse shaper 54 in accordance with a

predetermined characteristic such as raised cosine shaping. The shaped pulses are applied to a first input 56 of a comparator 58. A second input 60 of the comparator 58 is derived from the power sensing stage 36. The PA stage 34, the power sensing stage 36 and the comparator 58 form a servo loop so that the difference between the signals at the inputs 56, 60 of the comparator forms a control voltage which, after filtering in a low pass filter 62 having a loop bandwidth of the order of 500kHz, is applied to the PA stage 34. As the output power of the PA stage 34 is controllable continuously and monotonically, the specification of the PA stage 34 need not be linear which enables its specification to be relaxed and cheaper to implement.

The switch sequencer 50 is also connected to the PIN switch 32 and the PA stage 34 and provides an r.f. enable signal which causes the switch 32 and the stage 34 to be inoperative in the interpulse periods thereby preventing r.f. from leaking through to the receiver Rx (not shown) and the antenna 42.

The embodiment of the invention shown in Figure 5 is a variant on the embodiment shown in Figure 4 because the 12.5% duty cycle reference waveform is produced by means other than using the switch 48 and the switch sequencer 50. In Figure 5 an up-down counter 64 is arranged in response to external signals to provide clock signals to an input to a ROM 66 which stores digitally patterns of the 16 shapes of the power pulses. The ROM 66 has an input 68 for a 4-bit power level signal derived from a microcontroller 44. During the relevant period of the duty cycle the ROM 66 is clocked by the output from the counter 64 and provides as an output a sequence of digital values which simulate the desired power pulse shape. These digital values are applied to the digital to analogue converter 46 which provides a reference pulse waveform of the required magnitude and shape. The analogue waveform is applied to a low pass filter 70 which eliminates H.F. components of the quantised output of the digital-to- analogue converter 46. The output from the filter 70 is applied to input 56 of the comparator 58.

More particularly as the counter 64 is incremented, the ROM 66 produces a sequence of digital values corresponding to the desired leading edge. At the relevant desired power level, the count is held so that the input to the digital to analogue converter 46 remains unchanged. Thereafter the counter 64 is decremented and the sequence of digital values corresponding to the desired trailing edge is produced by the ROM 66. The counter 64 is reset to zero in the event of it not already having reached zero.

An r.f. enable line 72 is connected to the PIN switch 32 and the P.A. stage 34. The signal on the line 72 switches off the PIN switch 32 and the PA stage 34 during the interpulse periods to prevent r.f. leaking through to the receiver Rx and to the antenna 42.

The construction and operation of the remainder of the circuit is as described already with reference to Figure 4 and in the interests of brevity the description of the remainder of the circuit will not be repeated.

In the event of there being a large amount of non-linearity in the power sensing stage 36 there is a possibility that an 8-bit digital to analogue converter 46 will not have sufficient dynamic range to achieve an adequate raised cosine pulse shape for the lowest few transmitter power levels.

One method of overcoming this problem is to use a non-linear digital to analogue converter. Since the power sensing stage 36 may be non-linear, the use of a non-linear digital to analogue converter can effectively increase the dynamic range without increasing the number of bits at the signal input to the digital to analogue converter 46.

Figure 6 illustrates one method by which a pseudo non-linear digital-to-analogue converter can be implemented. The output from the ROM 66 is coupled to a standard digital-to-analogue converter 46 and to a control input of a programmable attenuator 74. The output of the converter 46 is connected to the input of the attenuator 74 which provides an analogue pulse power

reference waveform to the low pass filter 70. The attenuator 74 is used to switch the output range of the converter 46. A set of output ranges can be generated by a resistive ladder with analogue switch devices to select a desired tap on the ladder. The resistors in the ladder may be equal or unequal. In the latter case the resistor values can be chosen to provide a non-linear set of full scale outputs with a characteristic similar to that of the power sensing stage 36.

From reading the present disclosure, other modifications will be apparent to persons skilled in the art. Such modifications may involve other features which are already known in the design, manufacture and use of power amplifying arrangements and component parts thereof and which may be used instead of or in addition to features already described herein. Although claims have been formulated in this application to particular combinations of features, it should be understood that the scope of the disclosure of the present application also includes any novel feature or any novel combination of features disclosed herein either explicitly or implicitly or any generalisation thereof, whether or not it relates to the same invention as presently claimed in any claim and whether or not it mitigates any or all of the same technical problems as does the present invention. The applicants hereby give notice that new claims may be formulated to such features and/or combinations of such features during the prosecution of the present application or of any further application derived therefrom.

CLAIM(S)

1. A power amplifying arrangement comprising a power amplifier stage having an input for a signal to be amplified, an output for a signal amplified by the power amplifier and a control input for setting the instantaneous output power of the amplifier, a power sensor coupled to the output of the amplifier, the power sensor having a first output for the amplified signal and second output for providing a signal representative of the instantaneous value of the amplified signal, a comparator having first and second inputs and an output, the first input being coupled to the second output of the power sensor, the second input being coupled to means for providing a reference waveform of the output signal, the output being coupled to the control input of the amplifier.

2. An arrangement as claimed in Claim 1, wherein the means for providing a reference waveform comprises a device for producing digital data representative of a desired reference level, a digital-to-analogue converter for producing a voltage in response to the digital data, means for producing a pulse waveform from the voltage and a shaping filter for shaping the pulses of voltage to a predetermined shape.

3. An arrangement as claimed in Claim 1, wherein the means for providing a reference waveform comprises a ROM for storing digitally patterns of different waveform shapes, the ROM having a first input for a power level signal, a second input for clock signals and an output, a digital-to-analogue converter coupled to the output of the ROM and a clock signal removing filter coupled in the analogue signal path from the digital to analogue converter.

4. An arrangement as claimed in Claim 2 or 3, wherein an attenuator is connected to the signal output from the digital to analogue converter, the attenuator being switchable to provide a desired output range.

5. An arrangement as claimed in Claim 4, wherein the attenuator comprises a tapped resistive ladder adapted to provide

a non-linear set of full scale outputs.

6. An arrangement as claimed in any one of Claims 1 to 5, further comprising means for enabling the power amplifier stage so that it is activated whenever there is a pulse of power to be power amplified.

7. An arrangement as claimed in Claim 6, further comprising switching means having an input for a signal to be amplified and an output coupled to the input of the power amplifier stage, said switching means being actuated by the means for enabling the power amplifier stage.

8. A power amplifying arrangement constructed and arranged to operate substantially as hereinbefore described with reference to and as shown in the accompanying drawings.

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